

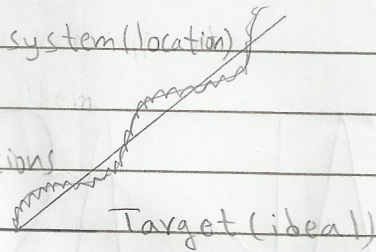
1. Introduction

- * Hand tool \rightarrow M/C is moved to w.p. to perform the function
- M/C \rightarrow W.P. is moved to M/C to perform the function

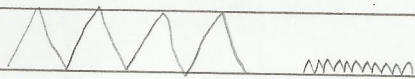
- Microscope is a m/c
- Micrometer is a hand tool

* Inclination, Straightness & roughness:

- Inclination: due to wrong fixing of system (location)
- Out of straightness: due to deflections due to wrong or unsufficient fix of w.p. or any part of the system



- Roughness: due to process conditions as speed, feed, etc.
- Roughness type needed depends on the needed application (Painting/Lubrication...)



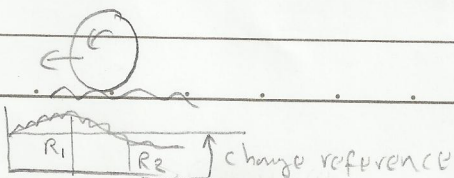
High 2 & Amp. Low 2 & Amp.

- Roughness is separated from straightness during measuring
- Big anvil \rightarrow out of straightness \rightarrow Large scale
- \rightarrow Low accuracy

Small anvil \Rightarrow Roughness \rightarrow Small scale

\rightarrow High accuracy

- Small anvil + large scale \rightarrow Breaking down
- 2 dimensions \rightarrow Flatness instead of straightness
- circular \rightarrow Eccentricity is considered



2- Thread measurements

* Main parameters in thread to be measured:

1. Outer diameter
2. Inner diameter
3. Effective diameter
4. Included angle
5. Flank angle
6. Pitch

* Used tools:

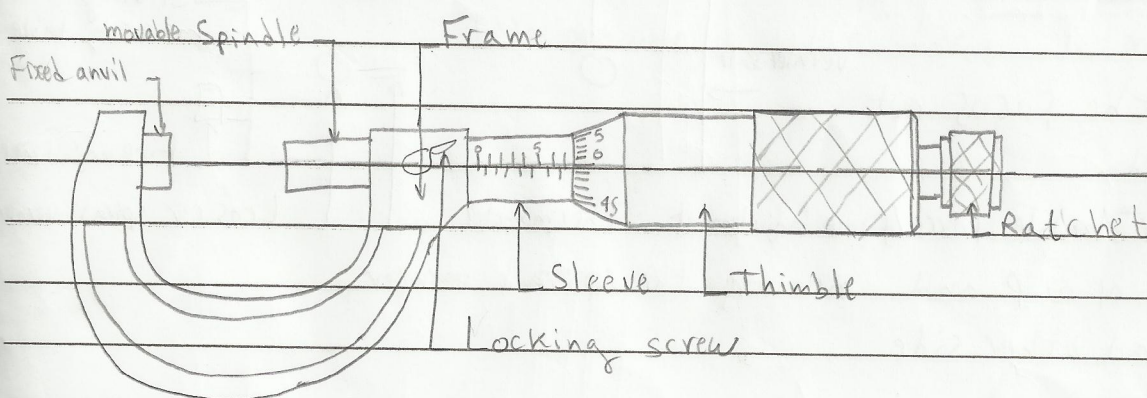
A. Hand tools:

1. Micrometer
2. Dial gauge

B. M/C tools:

1. Tool maker microscope
2. Projector
3. Abbe vertical metroscope
4. Abbe horizontal metroscope

A-1- Micrometer:

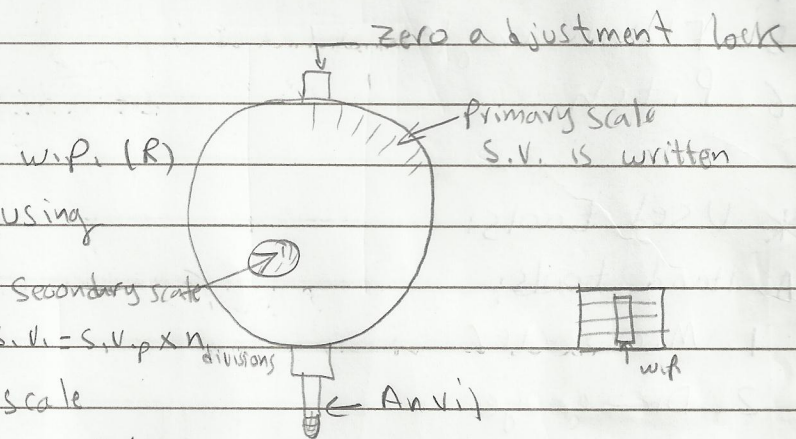


1. Hold the micrometer from frame
2. Define S.V. of micrometer

3. Close the micrometer to end or use block gauge to find zero error
4. Use ratchet at final closing
5. Consider the below scale
6. Reading - $N_1 \times S.V._{\text{main scale}} + N_2 \times S.V._{\text{thimble scale}} + \text{zero error} + \text{Anvil length}$
7. Repeat reading
- Consider reversed scale reading as in internal micrometer

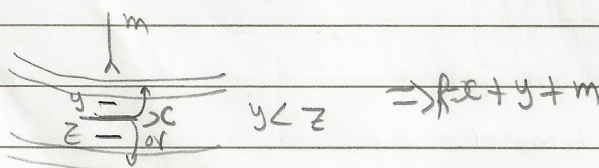
2. Dial indicator:

1. Use comparator
2. Take rough measure of w.p. (R_1)
3. Collect the reading (R) using block gauges (x)
4. Read the measurement $S.V. = S.V.p \times n_{\text{divisions}}$ of dial indicator (R_1) + scale
5. Read the measurement of w.p. (R_2) \Rightarrow max. reading
- $D_{w.p.} = x + R_2 - R_1$
- There are internal, external & depth dial gauges
- \hookrightarrow Anvils are considered



3. Abbe horizontal metroscope:

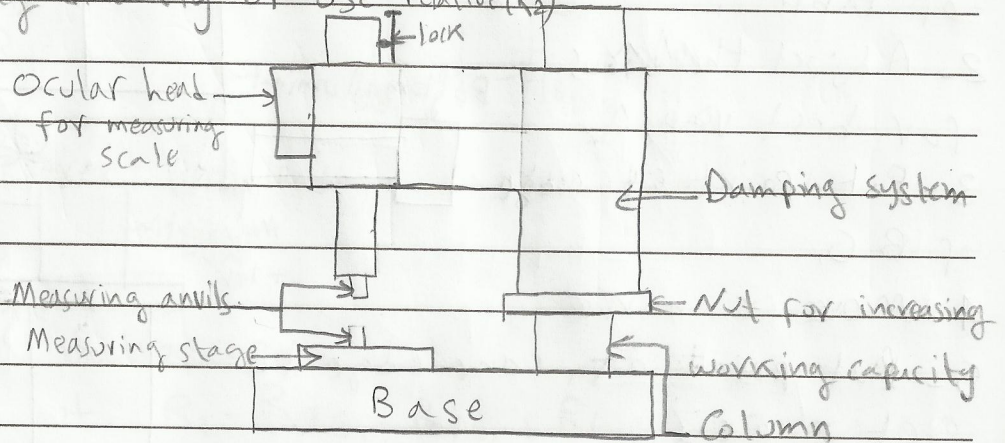
1. Adjust the w.p. under ocular head
2. Adjust the focus at ocular head
3. Move the table force/fine adjustment Thermometer to one side of w.p. and measure the spiral vernier
4. Repeat at other side



4- Abbe vertical metroscope:

1- Take initial reading including anvils & zero error (R_1)2- Take the reading directly or use relative (R_2)3- $D = R_2 - R_1$

Use lock to fix measurement

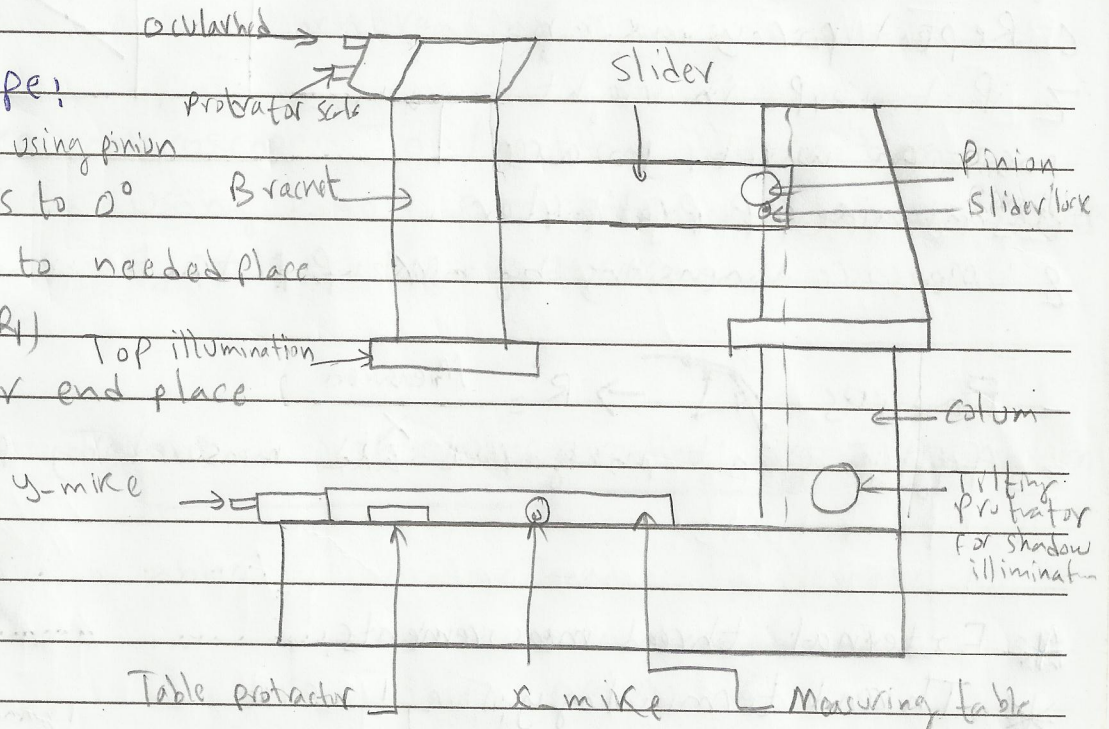


5- Microscope:

1- Adjust focus using pinion

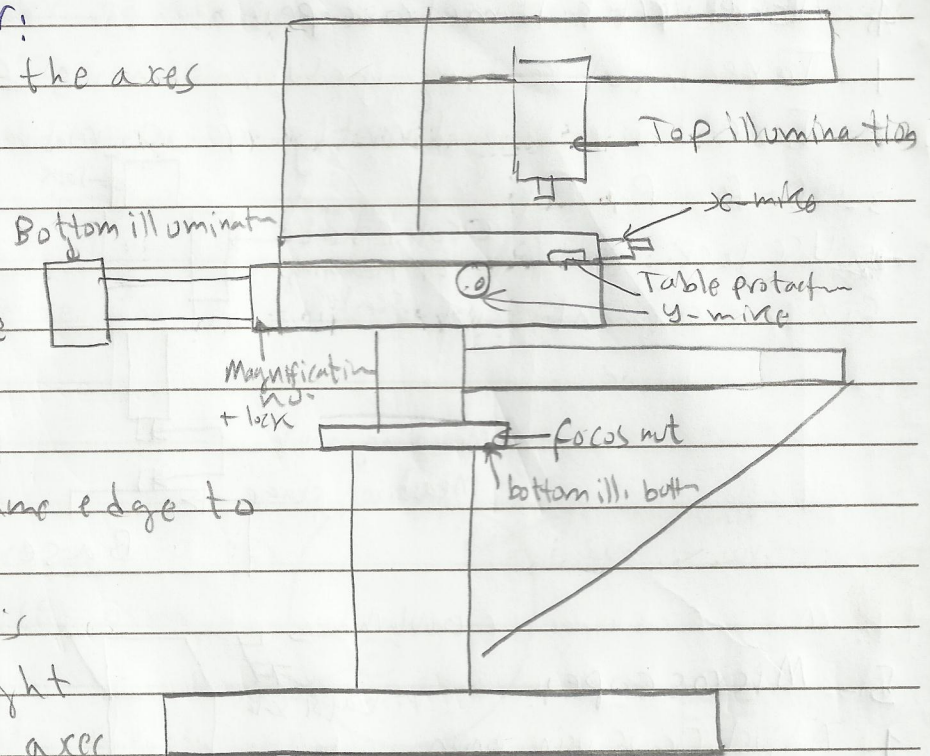
2- set proctors to 0°

3- Move mike to needed place

& take reading (R_1)4- Take R_2 for end place $D = R_2 - R_1$ 

6. Contour projector.

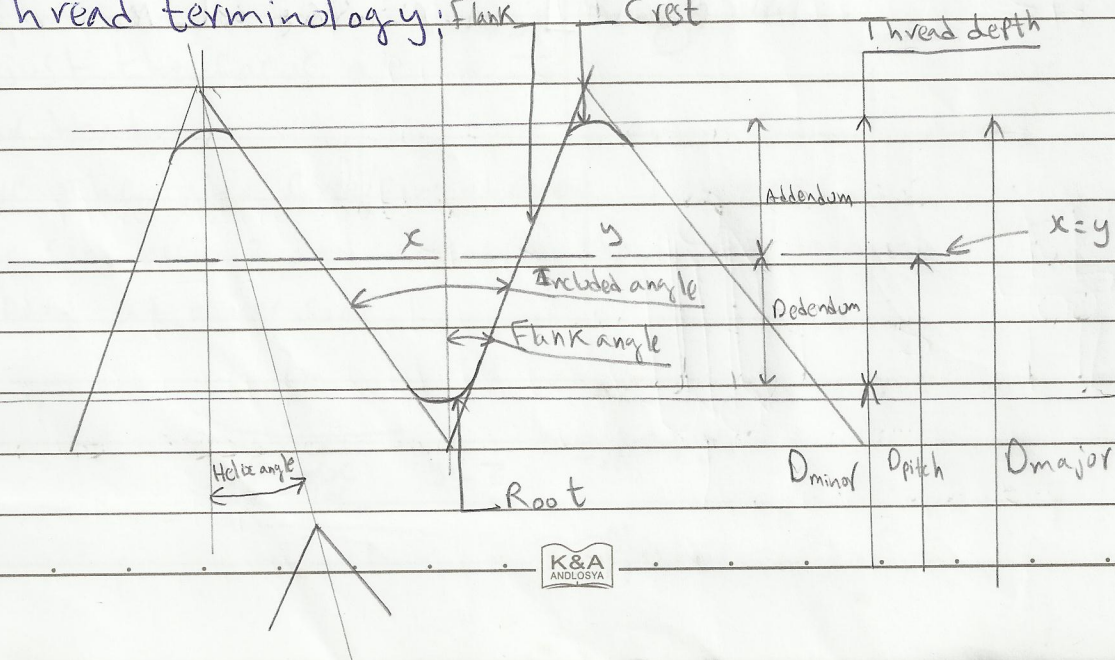
1. Use B.Gs to set the axes of table
2. Adjust the focus for best view
3. Put point at edge of B.G.
4. Move x-mike
5. Put point at same edge to get x-axis
6. Repeat for y-axis
7. Put w.p. in right position w.r.t. to axes using mikes & protractor
8. Measure dimensions by mikes & protractor



- Radius $\Rightarrow R = \frac{\text{Measured}}{X}$
- Angles aren't magnified and measured by protractor & mikes

A. External thread measurements;

* Thread terminology:



1 - Major diameter measurement:A - Hand tools:

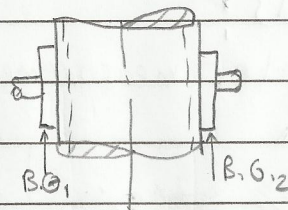
$$1. R_1 = R_{BG_1} + R_{BG_2} + \text{zero error}$$

$$2. R_2 = D_{\text{major}} + R_1$$

$$3. D_{\text{major}} = R_2 - R_1$$

4 - Repeat at different positions

$$5. D_{\text{major}} = \frac{\sum D_i}{n}$$

B - Abbe vertical metroscope:

- As hand tools but $R_1 = R_{BG_1} + R_{BG_2} + R_{\text{anvil}} + \text{zero error}$

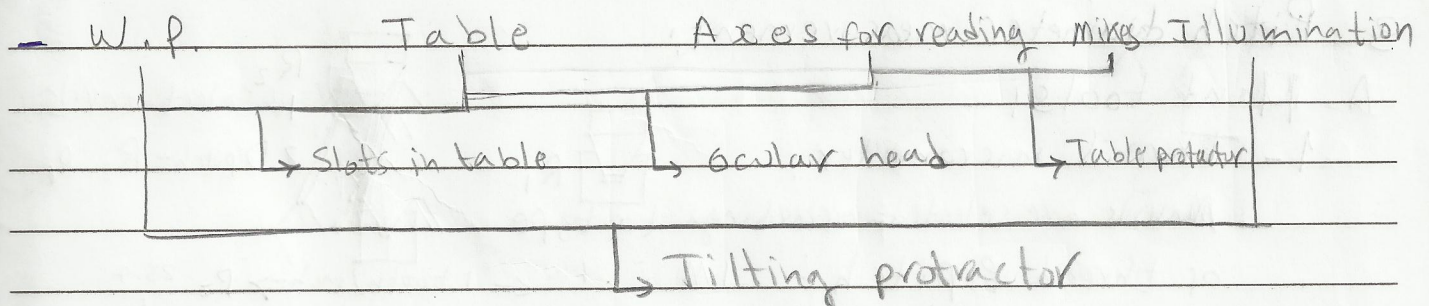
- Lock reading

C - Tool maker microscope: Top/bottom illumination

1 - Adjust focus using pinon for fixed thread between 2 centres

2 - Readings of all protractors are zero

$$3. D = R_2 - R_1$$

D - Contour projector: Top/bottom illumination

1 - Adjust focus using nut on B.G,

2 - Draw axes

4 - Adjust focus for w.p.

$$5. D = R_2 - R_1 \text{ at crests}$$

- W.p. is moved by hand or using Protractor to be with one axis (long way)

E - Abbe horizontal metroscope

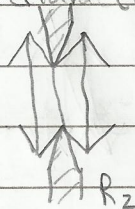
F - Dial gauge comparator

G - Cam shaft tester

2. Minor diameter measurement;

A. Hand tools;

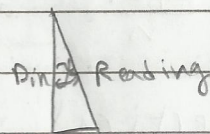
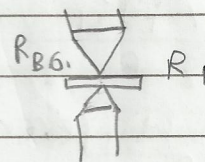
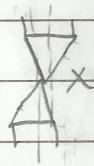
As major diameter measurement but anvils are different



$$\text{Reading} = R_2 - R_1 + R.R.G.$$

$$D_{\text{in}} = \text{Reading} \times \cos \psi$$

$$\tan \psi = \frac{\text{Lead}}{\pi D_{\text{eff}}}$$



B. T. M. microscope;

As major diameter measurement but tilting head occurs [Diff.]

C. Contour projector;

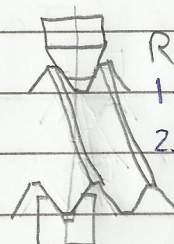
As major diameter measurement but tilting w.p. occurs [Diff.]

3. Pitch diameter measurement;

A. Hand tools;

1. Thread micrometer;

Anvils are selected according to type of thread & pitch



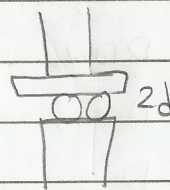
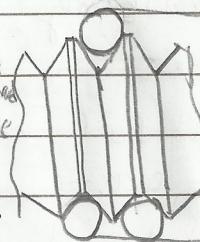
1. Select anvils
2. $D_{\text{pitch}} = R_2 - R_1$

$P = 1 \text{ mm} \rightarrow 2 \text{ M} \quad 1 \text{ W} \leftarrow 1 \text{ tooth/inch} \Rightarrow P = \frac{25.4}{1}$
 $P = 1 \text{ mm} \rightarrow 2 \text{ M} \quad 2 \text{ W}$

2. Three wire method

1. $d_{\text{best}} = \frac{P_{\text{std}}}{2} \sec \theta_{\text{std}} \rightarrow \text{larger} \rightarrow \text{to be over the}$
 Using thread gauge \rightarrow Flank angle

2. $S = D_e + d(1 + \cos \theta) \frac{P_{\text{std}}}{2} \rightarrow \theta_{\text{std}}$
 $d = \frac{2 d_{\text{measured}}}{2}$



2 for supporting

$\theta = 30^\circ, 27.5^\circ$

B. Abbe vertical microscope;

As 3-wire method

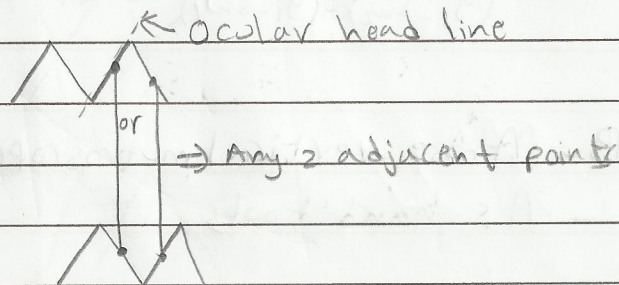
C. T. M. microscope; Top illumination

1- Using tilting protractor to eliminate shadow effect;

A- Take initial tilting ψ_1

B. Measure effective diameter D_{e1}

$$\frac{\psi_1 - \tan^{-1} \frac{P_{std}}{\pi D_{e1}}}{2} = 31.5^\circ$$



C. Tilt by ψ_2

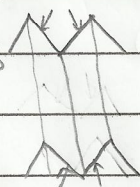
D. Measure effective diameter D_{e2}

E. Repeat till $\psi_{n+1} - \psi_n \leq 0.5^\circ$ (S.V. tilting protractor)

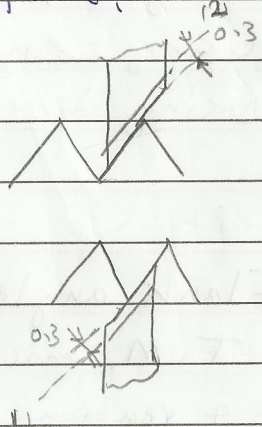
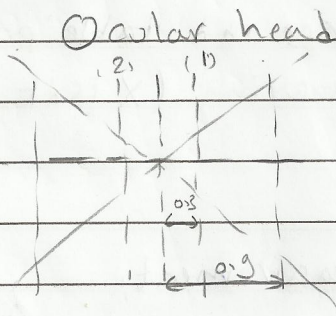
2. Using knives to eliminate shadow effect;

① tilting $= 0^\circ$

2 readings



Misalignment elimination



D. Contour projector;

- Use angle gauges under V blocks or 2 B.Gs and use bottom illumination

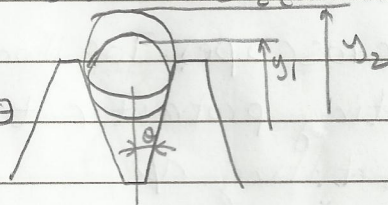
- Shadow is present but considered as random error

4 - Included angle measurement;

A - Hand tools;

- Use wires in Veff. and other more size

$$\sin \theta = \frac{dw_2 - dw_1}{(y_2 - dw_2) - (y_1 - dw_1)} \rightarrow \theta_{\text{incl.}} = 2\theta$$



B - Abbe vertical metroscope;

- As hand tools

C - T.M. microscope;

- Using ocular head (S.V.D) : Direct reading (2 up & 2 down)

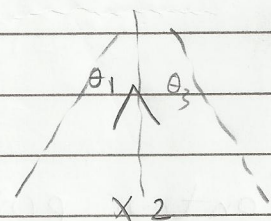
D - Projector;

- Using x & y mixes and table protractor considering (2 up & 2 down) (2 up & 2 down)
- Using direct measuring (X isn't considered)

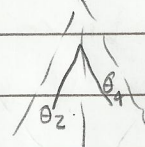
5 - Flank angle measurement;

A - T.M. microscope;

- 4 reading up & 4 reading down
- Using Knivg



$$\theta_L = \frac{\theta_1 + \theta_2}{2}, \quad \theta_R = \frac{\theta_3 + \theta_4}{2} \quad \text{for misalignment eliminat}$$



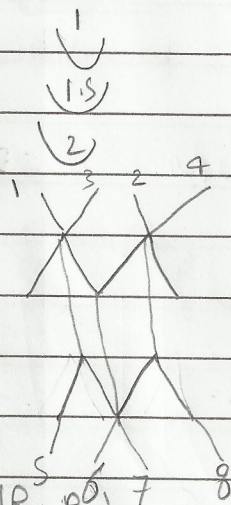
B - Con tour projector;

- As T.M. microscope by 2 ways

6- Pitch measurement;

1- T.M. microscope;

A- Template for pitch



B- 8 readings

$$p = \frac{(R_4 - R_3) + (R_2 - R_1) + (R_8 - R_5) + (R_6 - R_7)}{4}$$

2- Contour projector;

As T.M. microscope

3 - Thread terminologies

* Types of threads according to form of surface: Peaks locus

1 - Straight

2 - Taper: Gas & liquid tubes

Self sealing & fast clamping

3 - Horizontal: Spiral thread as in jaw chuck

* Types of threads according to form of profile: Shape of tooth

1 - Triangular

2 - Trapezoidal

3 - Square

4 - Round (in cover of food cans)

5 - B and S worm (Type of threads)

* According to no. of starts:

1 - Single

2 - Double

3 - Multi

Lead = IP

\hookrightarrow no. of starts

* According to sense of rotation:

1 - Right hand (Right hand to close)

2 - Left hand

* According to function:

1 - Fastener

2 - Power screw

* According to fineness:

1 - Coarse pitch (High loads)

2 - Fine pitch.

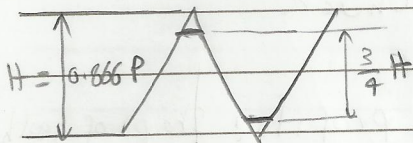
1 - Metric thread

French std

$$2\theta = 60^\circ$$

M ϕ x P

Determine \rightarrow Pitch size



$$0.866 = \frac{1}{2 \tan 30^\circ}$$

2 - Whitworth thread

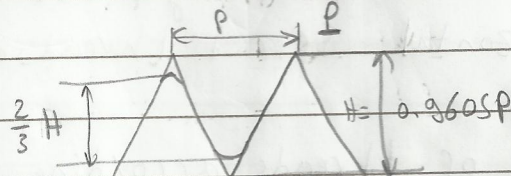
British std

$$2\theta = 55^\circ$$

W ϕ x P

Determine \rightarrow No. of teeth/inch

$$P = \frac{25.4}{\text{No. of teeth/inch}}$$

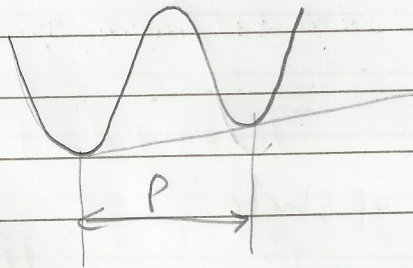


$$0.9605 = \frac{25.4}{2 \tan 27.5^\circ}$$

3 - Parallel pipe thread (G):

As Whitworth but round surface to prevent clearance

4 - Taper pipe thread:



* Thread manufacturing:

- 1 - Turning
- 2 - Rolling (High tensile bolts)
- 3 - Milling
- 4 - Tapping
- 5 - Casting

* Terminologies:

- 1- Screw thread: It is a continuous helical groove of specified cross-section produced on the external/internal surface
- 2- Crest: It is the top surface joining between 2 sides of thread
- 3- Root: It is the bottom of the groove between 2 flanks
- 4- Flank: It is the surface between crest & root
- 5- Lead: It is axial motion of nut on thread on rotating one rotation
- 6- Pitch: It is the distance measured parallel to axis of thread from point on thread to next corresponding point
- 7- Helix angle: It is the angle made by helix of thread at pitch line with axis
- 8- Flank angle: It is the angle between flank & normal to thread axis
- 9- Depth of thread: It is the distance between crest & root
- 10- Included angle: It is the angle between the flanks of thread measured in axial plane

* Errors in thread:

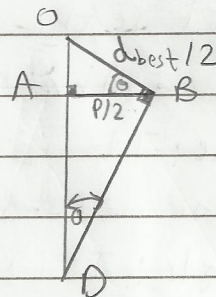
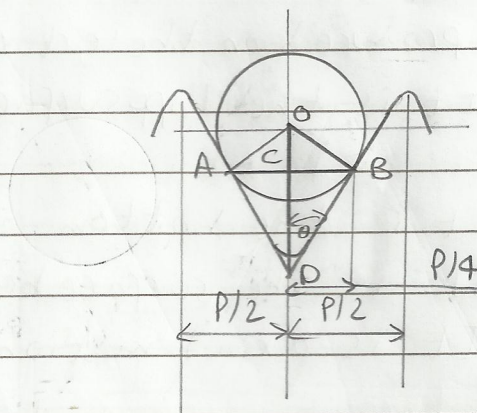
- 1- Major diameter error
- 2- Minor diameter error
- 3- Effective diameter error
- 4- Pitch error
- 5- Flank angle error
- 6- Included angle error

* Best wire diameter:

- Contact is at pitch line

$$\frac{d_{best}}{2} = \frac{P/2}{\cos \theta}$$

$$d_{best} = \frac{P}{2} \sec \theta$$



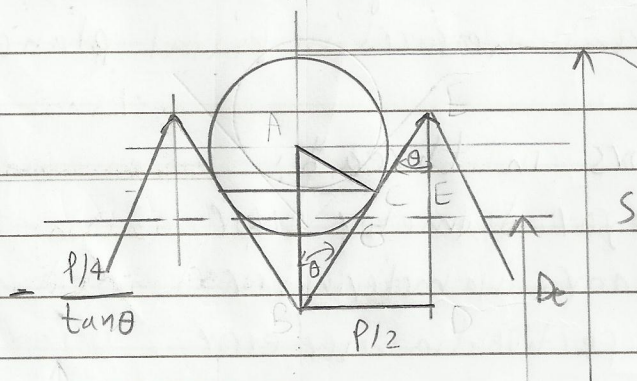
* Effective diameter calculations using wires method:

$$S = D_e + 2h + 2r$$

$$h = AB - BF = \frac{r}{\sin \theta} - BF$$

$$BF = GE = DE - DG = \frac{P/2}{\tan \theta} - \frac{P/4}{\tan \theta}$$

$$h = \frac{r}{\sin \theta} - \frac{P}{4 \tan \theta}$$

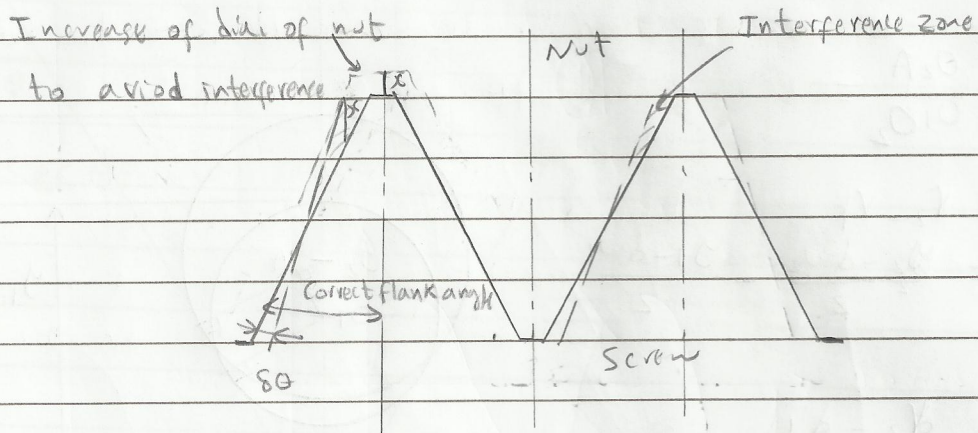


$$S = D_e + d + d \sec \theta - \frac{P}{2} \cot \theta$$

$$S = D_e + d(1 + \sec \theta) - \frac{P}{2} \cot \theta$$

$$D_e = S - d(1 + \sec \theta) + \frac{P}{2} \cot \theta$$

* Effect of flank angle error on (D_e) ;

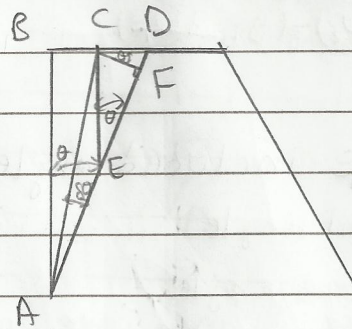


$$\sin \theta = \frac{FC}{AD}, \quad \sin \theta = \frac{FC}{CE}$$

For small (θ)

$$\sin \theta = \theta, \quad AC = AD$$

$$\sin \theta = \theta = \frac{FC}{AC}$$



$$\sin \theta = \frac{FC}{CE} = \frac{AC \theta}{CE}$$

$$\cos \theta = \frac{AB}{AD} = \frac{AB}{AC}$$

$$\cos \theta \times \sin \theta = \frac{AB}{CE} \theta, \quad (AB) \text{ Half tooth depth}$$

$$AB = \frac{h}{2}$$

$$\cos \theta \times \sin \theta = \frac{h}{2CE} \theta$$

$$CE = \Delta D_e = \frac{h}{2 \sin \theta} (\theta_R + \theta_L)$$

For metric thread

$$\Delta D_e = \frac{3 \times 10^{-3} P}{2 \sin \theta} (\theta_R + \theta_L) \times \frac{11^\circ}{180} = 0.0131 P (\theta_R + \theta_L)$$

For Whitworth thread

$$\Delta D_e = 0.0105 P (\theta_R + \theta_L)$$

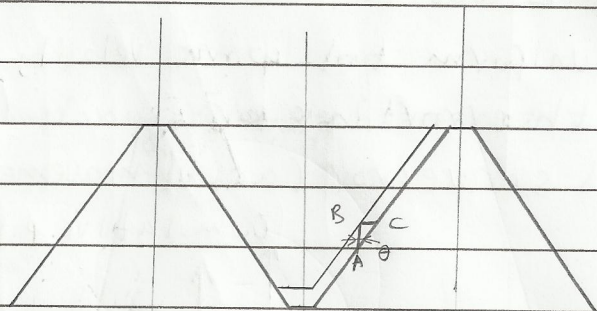
* Effect of pitch error on pitch diameter:

$$BC = \frac{\Delta P}{2}$$

$$AB = \frac{\Delta D_e}{2} = \frac{BC}{\tan \theta}$$

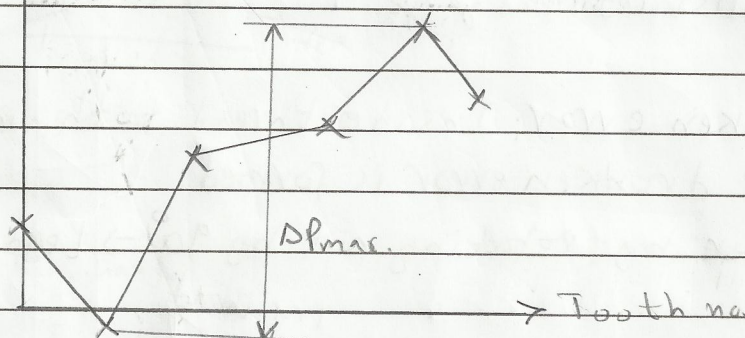
$$\Delta D_e = \Delta P_{\max} \cot \theta$$

Absolute



$$\text{No. of teeth} = \frac{H}{P} = \frac{0.7 D_o}{P}$$

Accumulated pitch error



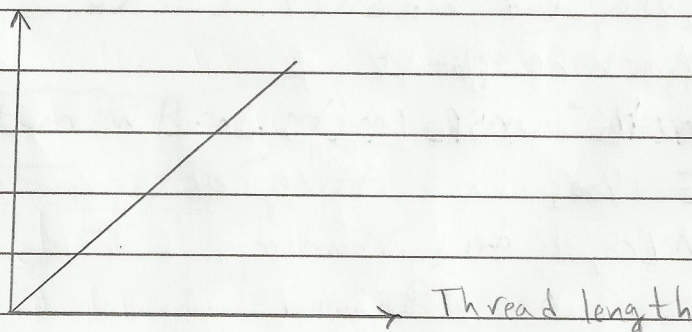
* Thread pitch errors:

1. Progressive error: The deviation (longer/shorter) of thread of pitch than nominal value due to:

A - Incorrect linear & angular velocity speed

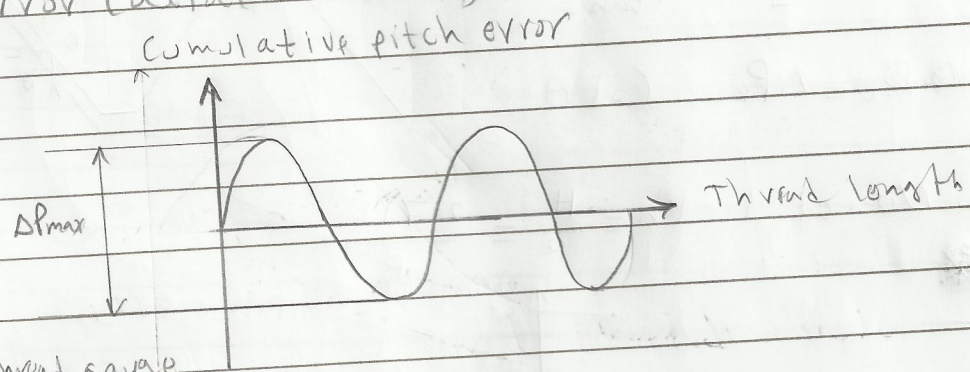
B - Incorrect gear train or an app. gear train between w.p.f. lead screw

Cumulative pitch error



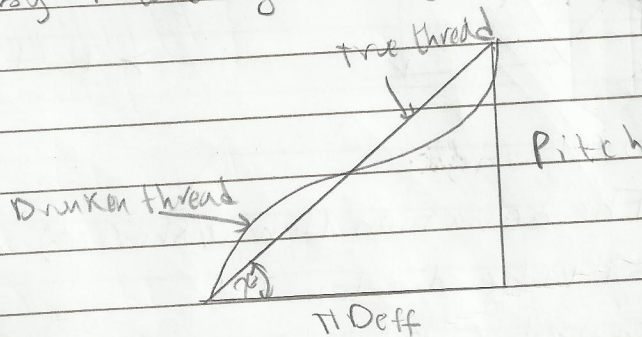
2. Periodic error: Repeated errors at regular intervals along the thread due to:

- A. Non-uniform tool-work velocity ratio (Variable)
- B. Teeth error in gears
- C. Lead screw error (axial movement)



3. Drunken error: Inside thread tooth in which helix is not true & drunken error is formed

Known by rotating nut by $90^\circ \Rightarrow \text{Lead} \neq \text{Pitch}$

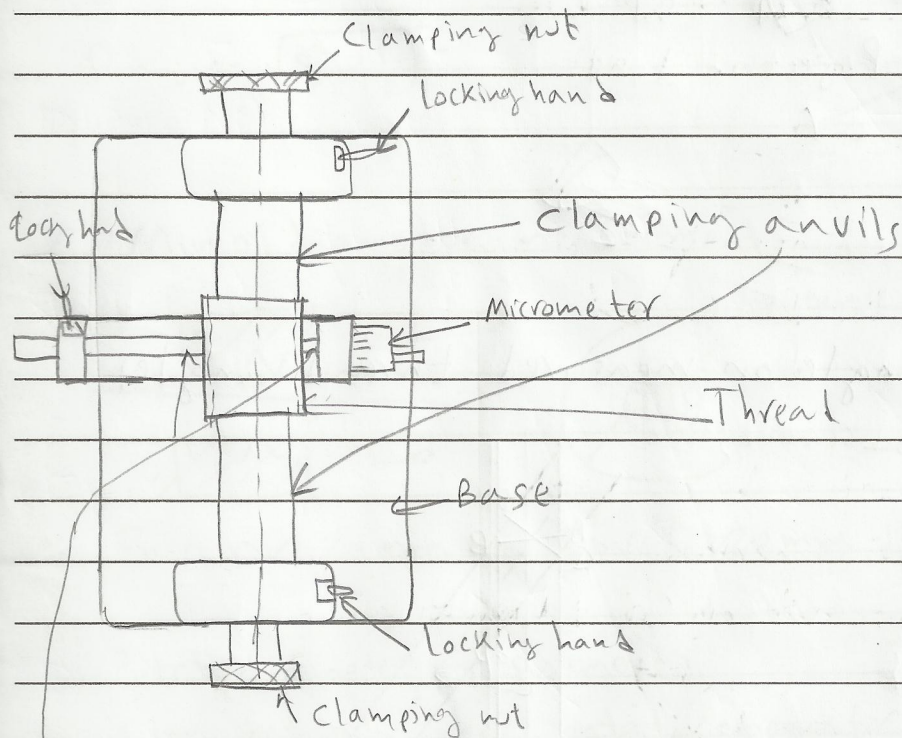


4. Irregular error: Pitch varies along the thread length in a regular manner due to:

- A. Machine fault
- B. Non-uniformity in the material
- C. Errors in cutting action
- D. M/cy disturbance

* Virtual effective diameter. It is diameter of thread containing all errors

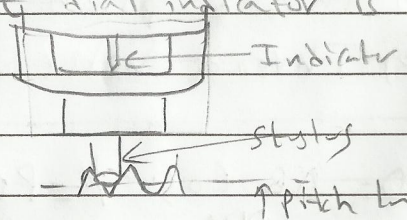
* Screw diameter measuring mic:



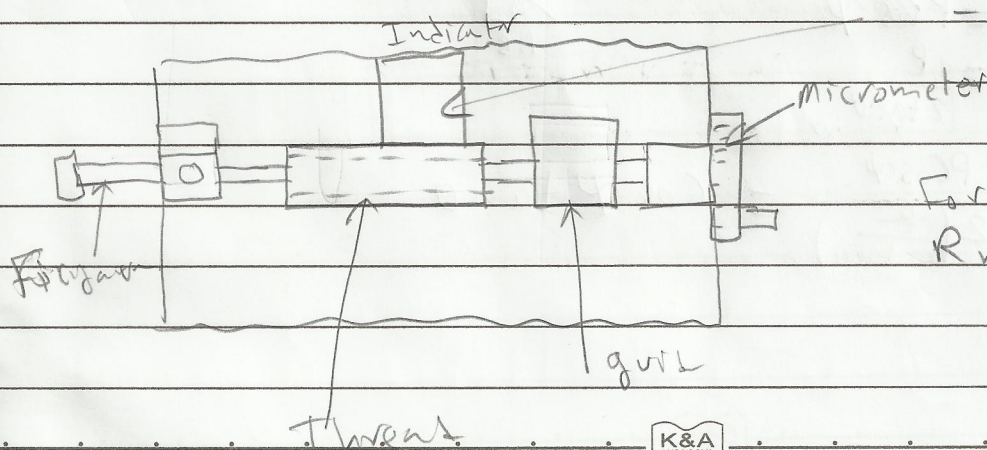
Measuring anvils for d_{major} , d_{eff}

* Floating carriage measuring mic:

As screw diameter measuring mic but dial indicator is

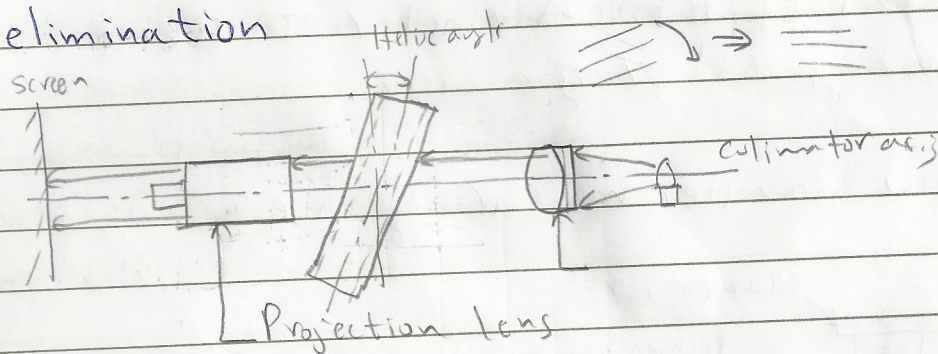


* Pitch measuring mic:

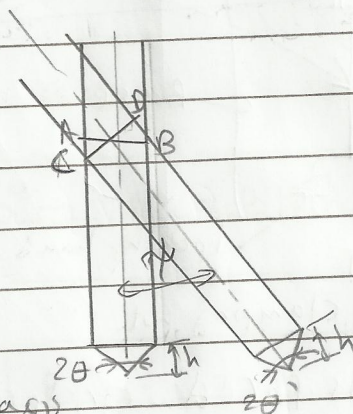
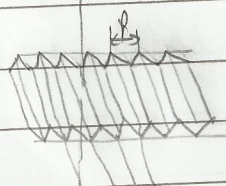
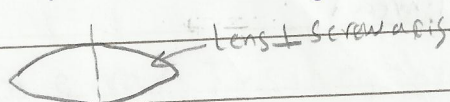


For same indicator readings R_{mic} is taken

* Shadow elimination



* Effect of helix angle on measured thread angle



(2θ) Thread angle in plane of screw axis

(2θ') Projected thread angle

(h) Tooth height

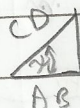
(p) Thread pitch

(ψ) Thread helix angle

$$CD = AB \cos \psi = P \cos \psi$$

$$\tan \theta = \frac{P/2}{h} \Rightarrow h = \frac{P}{2 \tan \theta}$$

$$\tan \theta' = \frac{CD/2}{h} = \frac{P \cos \psi}{2 \left(\frac{P}{2 \tan \theta} \right)} = \cos \psi \tan \theta$$



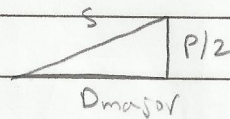
B - Internal thread measurements: Bottom illumination is used

1 - Major diameter measurement:

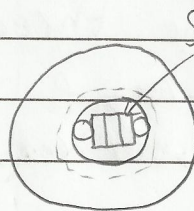
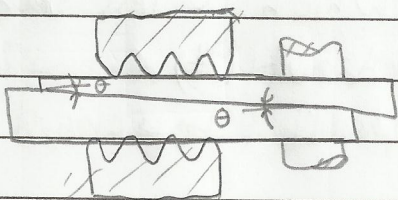


Inclined by helix

$$D_{\text{major}} = \sqrt{S^2 + \left(\frac{P}{2}\right)^2}$$



2 - Minor diameter measurement:



Slip gauge



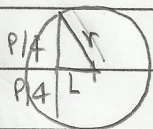
X \Rightarrow should be chamfered

For $D < 20 \text{ mm}$

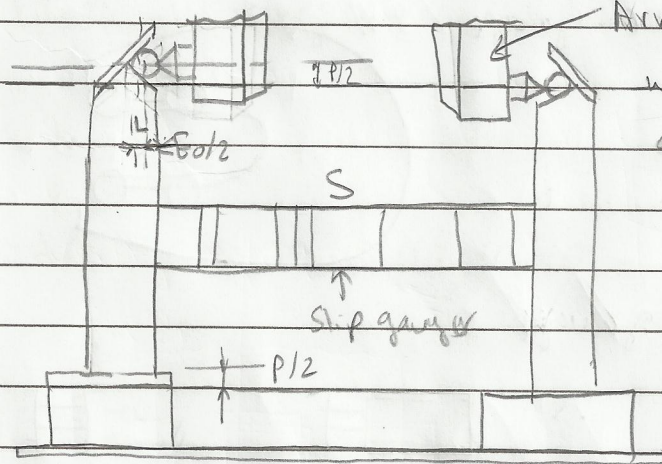
For $D > 20 \text{ mm}$ (Long-time method \Rightarrow S.V. = 0.001 mm)

3 - Pitch diameter measurement:

- Using internal horizontal comparator



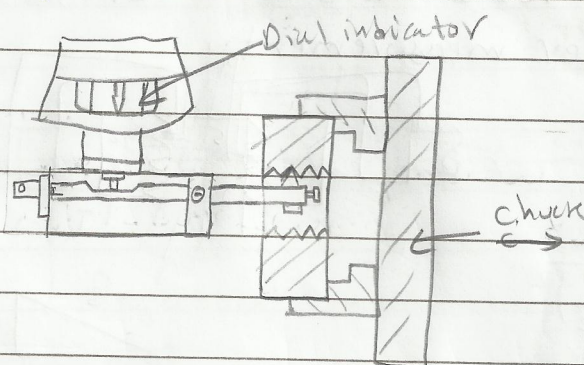
$$L = \sqrt{r^2 + \left(\frac{P}{4}\right)^2}$$



Arms of measuring mic with ball ended anvils of bus wire size

$$D_0 = S + E_0 + 2L$$

4. Pitch measurement:

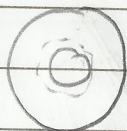


5. Flank angle measurement:

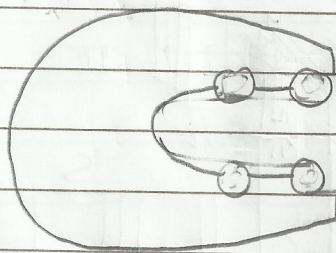
- Using plaster cast of the thread which is less than half the diameter of thread & lifted out ($\frac{1}{2}$)
- To avoid distortion, plaster cast shouldn't be screwed
- Using 3 balls

* Checking screws: Go/NO GO [V.E.D.]

1. Thread ring gauge



2. Thread caliper gauge



3. Thread plug gauge

